Peculiarities of light scattering near an edge of a thin opaque screen. Part 2

Yu.I. Terent'ev

Institute of Atmospheric Optics,
Siberian Branch of the Russian Academy of Sciences, Tomsk

Received October 26, 2000

It has been found experimentally that rays deflected near an edge of a thin opaque screen in the direction outward the screen shadow were deflected by edges of a slit only in the direction opposite to the shadows of the slit's screens. The slit was spaced by 3 mm from the screen.

It has been found experimentally[1] that rays deflected near an edge of a thin opaque screen toward or outward the screen were repeatedly deflected by the second screen only in the directions toward the screen or outward it. (The second screen was separated by less than 4.5 mm from the first one.)

In those experiments, the following earlier discovered experimental facts and regularities were taken into account:

1. Above the screen surfaces there exist zones of deflection of light rays. The length of such zones many times exceeds the wavelength of visible radiation. Rays in these zones are deflected in the opposite directions relative to the initial direction.[2] In this case, deflection (diffraction) angles are characterized by the equation[3]:

$$h_z = (259.5 - 0.786\ \varepsilon)/\varepsilon,$$

where h_z is the distance from the screen to the point of ray deflection, in μm; ε is the deflection angle, in minutes of arc.

2. The edge light from a screen consists of the rays deflected toward the screen (this rays form the main component) and the rays reflected from the screen edge, partially after their prior deflection in the zone (these rays form the so-called Sommerfeld component[2]).

3. The phases of the edge components deflected from the screen and toward the shadow area, respectively, experience the initial phase shift by 0.5π in the direction of their propagation and in the opposite direction with respect to the phase of the incident wave.[4–6] As a result, the phase shift between them is equal to π. (Ref. 4).

Having experienced the phase shift by −0.5π at deflection toward the screen and by π at reflection, the Sommerfeld component passing to the illuminated side proves to be in phase with the main component and intensify it. The Sommerfeld component passing in the shadow area after the loss of a half-wave at deflection, conversely, proves to be in antiphase with the main component of the same direction and weakens it.

4. If the screen is covered with a soot layer, the energy in the edge wave is significantly redistributed from the illuminated side to the shadow area, because soot partially absorbs the Sommerfeld component, and it intensifies less the main component in the shadow area and weakens it on the opposite side.[2]

5. The amplitude of the edge light from a thin weakly absorbing screen with a straight edge is inversely proportional to the tangent of ε (Refs. 4 and 7).

To confirm the established regularities of ray deflection near screens, experiments by the scheme shown in Fig. 1 have been conducted. In this figure, S' is the image of a slit S 36 μm wide (it is shown as a curve of light intensity distribution over its width); Sc_1 is a thin screen (blade) set in the plane of S' and cutting off a half of the light flux from an objective; S_1 is a slit between the two blades Sc_2 and Sc_3 with the width $t = 0.1$ mm (S_1 is parallel to the edge of Sc_1 and spaced by $x = 3$ mm from S' and by $L = 97.6$ mm from the plane of scanning of the diffraction pattern by a 0.1-mm wide slit along the axis H; g. sh. is the geometric shadow of Sc_2 and Sc_3.

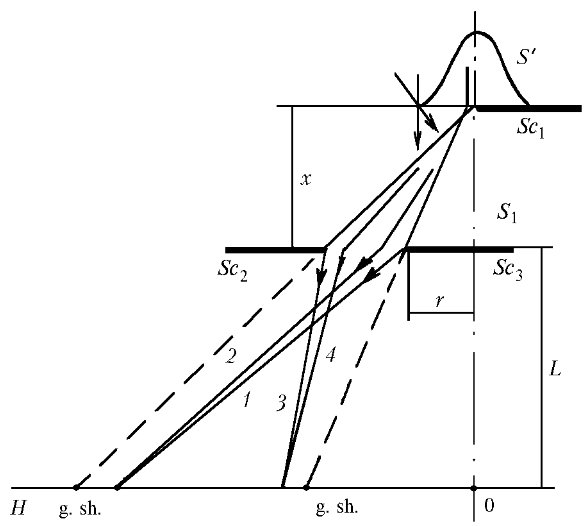

Fig. 1. Geometry of the experiment on diffraction of edge light passing from the zone near an edge of the thin opaque screen in the direction opposite to the screen's shadow.

0235-6880/01/01 5-03 $02.00 © 2001 Institute of Atmospheric Optics

The slit S is illuminated by a parallel beam of green light at $\lambda = 0.53$ μm. The projection of the slit S_1 has the width $t(L + x)/x = 3.41$ mm. The slit S_1 is illuminated by the edge flux passing on the side opposite to the shadow of Sc_1 from the zone near its edge. This flux almost completely consists of the rays deflected outward the screen due to the soot cover applied on the screen. Soot prevents reflection of rays deflected toward the screen and incident on its edge.

To exclude overlapping of the incident light on the edge light, the right-hand side edge of a 1.5-mm wide aperture slit s_0 placed in front of the objective was set at the beam axis. In this case, its left-hand side screen limited the flux by the first minimum in the diffraction pattern of S. The slit S_1 was spaced by $r = 117$ μm from the axis of the incident beam. As a result, edge rays deflected in a narrow layer of the deflection zone of Sc_1 passed through the deflection zones of the screens forming the slit S_1. This narrow layer had a width about 1 μm. This allowed it to be treated as a point-like source near an edge of Sc_1, when determining the boundaries of the geometric shadow of the screens of S_1. At such r, the rays from the deflection zone near the right-hand side edge of s_0 passing near Sc_2 and Sc_3 had low intensity as compared with the intensity J of the edge light from the deflection zone of Sc_1. The screens Sc_2 and Sc_3 were covered with as well. At such an angular width of the slit t/x, the rays deflected from Sc_2 and Sc_3 had very low intensity beyond the projection of the slit.

In Fig. 2, curves *1* and *2* characterize the distribution of J in the diffraction pattern from S_1 and in the edge light from Sc_1 in the scanning plane. In this figure, H is measured from the axis S'.

Curve *1* in Fig. 2*a* shows that the light practically does not penetrate into the area of the geometric shadows of Sc_2 and Sc_3. Consequently, the rays *1*, *2*, *3*, and *4*, which were deflected in the deflection zone of Sc_1 outward the screen, in the deflection zones of the screens Sc_2 and Sc_3 were repeatedly deflected only outward the screen.

Low illumination (marked by asterisks) in the shadow of Sc_2 and Sc_3 near the geometric shadow was mostly formed by the rays reflected from the edge of Sc_1 in the direction of S_1, being incompletely absorbed by soot after deflection and incidence on the screen, since after deflection and incidence of these rays on the edges of Sc_2 and Sc_3 some of them were reflected (because of incomplete absorption by soot) to the screen shadow.

In this figure, the area bounded by curve *1* is proportional to the light flux forming the diffraction pattern. This area is much less than the area bounded by curve *2* and verticals coming from the geometric shadow, which is proportional to the edge flux incident on S_1.

The unbalance between the fluxes incident on the slit and coming from it is indicative of incomplete absorption of rays deflected toward Sc_1 by soot and of their following absorption by soot on the screens Sc_2 and Sc_3 after deflection and incidence on the edges of these screens.

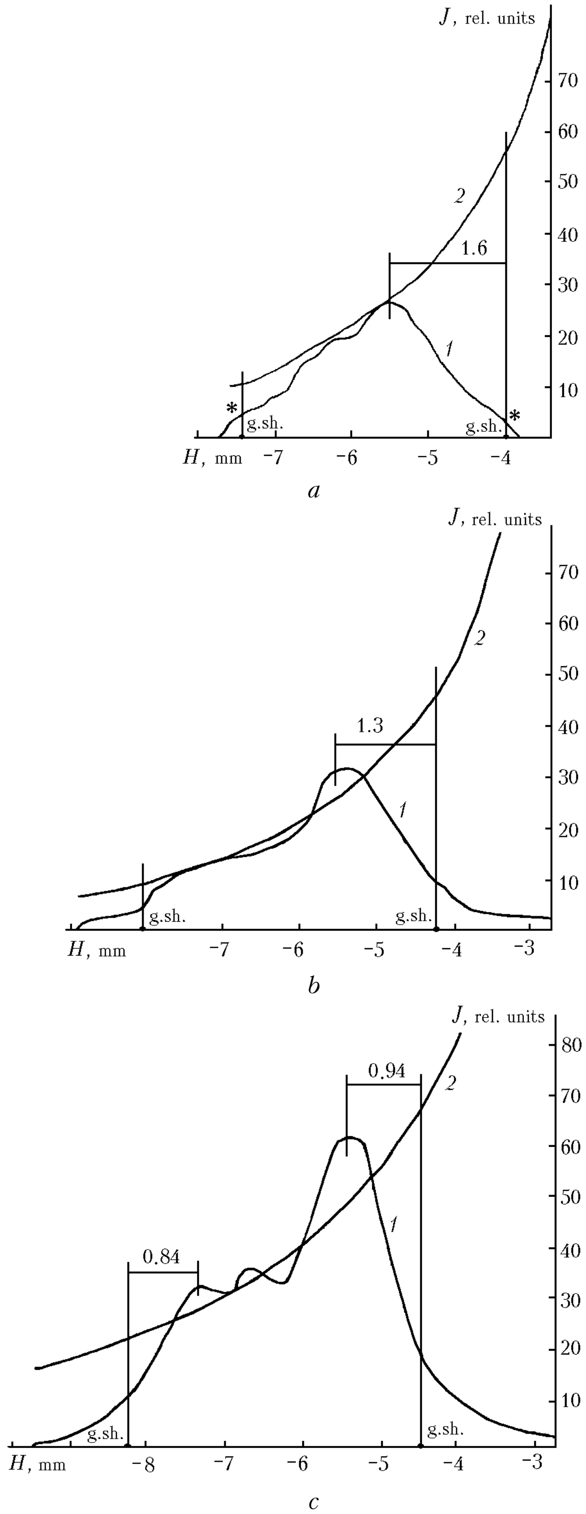

Fig. 2. Distribution of light intensity in the edge wave passing in the direction opposite to the screen shadow and the intensity distribution in the diffraction pattern formed by this wave: sooted screen Sc_1 and slit screens Sc_2 and Sc_3 (*a*), clean slit screens (*b*), clean Sc_1, Sc_2, and Sc_3 (*c*).

In Fig. 2*b*, curve *1* characterizes the distribution of J in the diffraction pattern of S_1 with clean Sc_2 and Sc_3. In this case, the residual rays first deflected to Sc_1 and reflected from its edge due to incomplete absorption by soot and then deflected to Sc_2 and Sc_3 and reflected from their edges were no longer absorbed. As a result, a marked illumination was observed in the shadow of Sc_2 and Sc_3, and J in the diffraction pattern increases within the slit projection.

Once the soot was removed from Sc_1 as well, the intensity of rays deflected to the screen and reflected from its edge increased in the edge flux passing from the screen toward the slit. This is seen from the increase of the total value of J of the edge light (Fig. 2*c*).

As a result, the intensity of rays deflected to Sc_2 and Sc_3 and reflected from them increased. This caused even stronger increase of illumination in the area of screen shadows (see Fig. 2*c*). The light intensity within the slit projection increased simultaneously, and diffraction fringes became ordered.

As is seen, the rays deflected from Sc_1 were then deflected near Sc_2 and Sc_3 only toward the slit center, and the rays deflected to Sc_1 were then deflected to the shadow of Sc_2 and Sc_3. This confirms the conclusion drawn in the Part 1 of this paper: after deflection by the first screen, the rays are then deflected by the following screens in the same direction (the ray path $x < 4.5$ mm).

In the case corresponding to Fig. 2*a*, the rays *1* strongly deflected in the zone of Sc_3 interfered with the rays *2* deflected in the weak part of the deflection zone of Sc_3. Thus, they formed the diffraction pattern of Sc_3. The rays *3* strongly deflected in the zone of Sc_2 interfered with the rays *4* deflected in the weak part of the deflection zone of Sc_2 and formed the diffraction pattern of Sc_2.

Since the intensity of light incident on S_1 increased sharply in the direction from Sc_2 to Sc_3, the intensity J in the diffraction pattern of Sc_3 far exceeded that in the pattern of Sc_2. These patterns overlapped giving the resulting diffraction pattern described by curve *1*.

The matching of the patterns (coincidence of peaks and dips) obviously depends on x, L, and t.

As the rays deflected toward the screens in the deflection zones of Sc_2 and Sc_3 appear in the interfering fluxes and their part increases, the main maximum (first maximum in the diffraction pattern of Sc_3) gradually shifts toward the geometric shadow. This is indicative of the change of phase relationships in the flux forming the diffraction pattern.

In the case that all screens were clean, the distance from the main maximum to the geometric shadow (0.94 mm) is equal to the distance calculated by Eq. (4) from Ref. 3 at the initial propagation difference between the interfering rays $0.5\lambda/2$.

Since almost all rays deflected in the deflection zones of Sc_2 and Sc_3 were deflected outward the screens, the light intensity in Fig. 2*a* near the geometric shadow is low at the initial sections of the projection of the deflection zones. As the rays deflected toward the screens appeared in the light flux from S_1 (after removal of soot from the screens), the intensity increased up to the values comparable with J of the edge light at the corresponding points in the absence of S_1.

References

1. Yu.I. Terent'ev, Atmos. Oceanic Opt. **13**, No. 12, 1011–1014 (2000).
2. Yu.I. Terent'ev, Atmos. Oceanic Opt. **8**, No. 4, 262–268 (1995).
3. Yu.I. Terent'ev, Atmos. Oceanic Opt. **11**, No. 12, 1088–1092 (1998).
4. Yu.I. Terent'ev, Atm. Opt. **2**, No. 11, 970–974 (1989).
5. Yu.I. Terent'ev, Atmos. Oceanic Opt. **9**, No. 3, 202–208 (1996).
6. Yu.I. Terent'ev, Atmos. Oceanic Opt. **12**, No. 5, 395–397 (1999).
7. Yu.I. Terent'ev, Atm. Opt. **2**, No. 11, 975–981 (1989).